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Electron Identification at CDF *

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Abstract

Electron identification at CDF is performed using the information of lateral and longitudinal shower spread, the track-cluster position match and the energy-momentum match. The tracking chamber with a solenoidal magnetic field at CDF is powerful for rejecting the backgrounds such as the $\pi^{\pm}$-π^0 overlaps, the π^0 /γ conversions and interactive $\pi^{\pm}$ in electromagnetic calorimeter: The energy-momentum match cut can decrease the background due to the $\pi^{\pm}$-π^0 overlaps for non-isolated electrons with Et above 10 GeV by a factor of 20 . The conversion electrons are identified using track information with an efficiency of 80 ± 3 %. The charge of electrons from W decay can be determined in the pseudorapidity range of $|\eta| < 1.7$ at CDF. The charge determination is useful for background estimation of Drell-Yan physics and heavy flavour physics.

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1. Introduction

The CDF proton-antiproton collision experiment logged data on tape corresponding to an integrated luminosity of 4.4 pb^{-1} between September 1988 and May 1989. The electron identification algorithm at CDF has been studied using this data sample. The CDF detector is a 4π general purpose detector with a solenoidal magnet. The electromagnetic calorimeter is divided into the central ($|\eta| < 1.1$), plug ($1.1 < |\eta| < 2.4$) and forward ($2.2 < |\eta| < 4.2$) regions. The electron identification in the central and plug region will be discussed.

In section 2, we describe briefly the CDF detector relating to the electron identification in the central and plug region. Further details of the CDF detector is obtained elsewhere[1]. The electron identification is described with a stress on the energy-momentum match in the central and plug region in section 3. The rejection of conversion electrons and the charge determination of electrons are discussed in sections 4 and 5, respectively.

2. The CDF Detector

The central tracking chamber (CTC) inside of a 1.5 Tesla solenoidal magnet provides charged particle tracking and momentum reconstruction. The chamber has 84 sense layers grouped into 9 superlayers with radii between 31 and 132cm. Five of superlayers consist of 12 axial wires and four stereo superlayers consist of 6 sense wires tilted by $\pm 3°$ to the beam direction which gives the z hit position. The CTC gives the momentum resolution of $\delta P_T/P_T^2 = 0.0011$ (GeV/c^{-1}) in the pseudorapidity region of $|\eta| < 1.0$ for vertex constraint tracks.

The innermost detector required in electron identification is the Vertex Time Projection Chamber (VTPC) with an active area of radii between 6.8 and 21 cm. The VTPC provides good r-z reconstruction in the pseudorapidity range of $|\eta| < 3.5$ and is used to determine the z position of the primary event vertex with an accuracy of ~3mm rms. It is also used for the rejection of conversion electrons at its outside wall, and the track-cluster position match in the plug region.

The electromagnetic (hadron) calorimeter uses lead sheets (iron plates) alternated with scintillator as the active medium in the central region, and with propotional chamber with cathod pad readout in the plug and forward region. All calorimeters have a tower geometry where each tower is projective, i.e., points at the interaction region. The size of tower was optimized to give the lateral spread information of jets and electrons, and is 0.1 in eta and 15° (central region) or 5° (plug and forward regions) in azimuthal angle. Since

the central electromagnetic calorimeter (CEM) has coarser lateral segmentation than the plug and forward electromagnetic calorimeters (PEM and FEM), it has a layer of proportional chamber (CES) placed approximately at a shower maximum (6 radiation length) to obtain accurate shower centroid and lateral shower profile. The electromagnetic calorimeters have a spatial resolution of ~ 2 mm over the full solid angle. In the PEM, there are three samples in depth to provide the longitudinal shower shape information.

3. Electron Identification

Electron identification at CDF is performed using the information of lateral and longitudinal shower shape, the track-cluster position match and the energy-momentum match. The above information is given by the following quantities in the central and plug region:

Table 1. Measured Quantities for Electron Identification

information	central region	plug region
longitudinal shower shape	HAD/EM	HAD/EM $\chi^2_{\text{longitudinal}}$
lateral shower shape	χ^2_{strip} χ^2_{wire} LSHR	$\chi^2_{\text{lateral 5x5}}$ $\chi^2_{\text{lateral 3x3}}$
track-cluster position match	ΔZ, $\Delta r\phi$	$\Delta\eta$, $\Delta\phi$
momentum-energy match	E/P	E/P (restricted region $\lvert\eta\rvert < 1.7$)
Isolation	ISOL(R < 0.4)	ISOL(R < 0.4)
	Border	

Here,

(a) Had/EM is the ratio of hadronic to electromagnetic energy deposition.

(b) $\chi^2_{\text{longitudinal}}$ is the deviation of the measured longitudinal shower shape from testbeam electron shower in the PEM.

(c) χ^2_{strip}, χ^2_{wire} and LSHR are the deviation of the measured lateral shower shape from testbeam electron shower with CES strips, CES wires and CEM three towers, respectively.

(d) $\chi^2_{\text{lateral 3x3}}$ and $\chi^2_{\text{lateral 5x5}}$ are the deviation of the measured lateral shower shape from testbeam electron shower with PEM 3x3 towers and PEM 5x5 towers in $\eta x\phi$, respectively.

(e) ΔZ and $\Delta r\phi$ are the geometrical matching of the shower centroid measured in CES with a track reconstructed in CTC in the z and ϕ directions, respectively.

(f) $\Delta\eta$ and $\Delta\phi$ are the geometrical matching of the shower centroid measured in PEM towers with a track reconstructed in VTPC or CTC in the η and ϕ directions, respectively.

(g) E/P is the ratio of the EM cluster energy to the momentum of an associated track.

(h) ISOL(R<0.4) is the energy around the electron within a cone with a radius of 0.4 in η - ϕ coordinates, divided by the electron energy.

(i) Border Tower Et is the sum of the transverse energy measured in CEM towers adjacent to the electron cluster.

Identifying electrons with the above quantities, the CDF obtained results on W/Z physics and heavy flavour physics as described elsewhere[2]-[5]. The efficiencies for electron identification were 86±3% and 96±2% for tight and loose cuts, respectively[5].

How Effective is the E/P cut ?

To see how effective the E/P cut is, we used an event sample triggered by requiring two or more EM clusters with Et > 10 GeV (Diphoton_10 trigger) at an integrated luminosity of ~ $1pb^{-1}$. From this event sample, we selected central electrons and π^0/γ's with Et >10 GeV using the information of longitudinal and lateral shower shape, i.e., Had/EM < 0.055 + 0.045 x E (GeV)/100 and LSHR < 0.2. 14,278 clusters passed these cuts.

Out of 14,278 clusters, there were 7,639 (54%) clusters without any associated tracks, 4,674 (33%) clusters with one track and 1,872 (13%) clusters with two or more tracks. The E/P distribution is shown for the EM clusters with one track in Fig.1. Applying the E/P cut of $0.6 < E/P < 1.4$, we could reduce the 4,674 clusters to 767 (16%) clusters. In Figs. 2a - 2d, ΔZ and $\Delta\phi$ are shown before and after the E/P cut of $0.6 < E/P < 1.4$. It shows that the E/P cut decreased the background contamination from ~45% to ~3% in the window of track-cluster postion match of $|\Delta Z| < 3$ cm and $|\Delta\phi| < 0.02$ radians. In this event sample, the number of non-isolated prompt electrons is estimated to be 580. Thus the E/P cut decreases the background for non-isolated electrons with Et > 10 GeV by a factor of 20. This background is mainly due to the $\pi^{\pm}$-π^0 overlapping.

4. Rejection of Conversion Electron

The conversion of π^0/γ at the material inside of the CTC and the π^0 Dalitz decays give rise to backgrounds of non-prompt electrons. Such electron pairs are rejected using tracking information at CDF. The conversion electrons were identified by requiring that

(a) there is no track in VTPC (# hits found/ # hits expected < 0.2) or

(b) $|S| < 2$cm and $\Delta\theta < 5°$ or $M_{2tracks} < 0.5$ GeV , where $\Delta\theta$ is the minimum difference in polar angle between two tracks, S is the separation of two track circles in the x-y plane, $S = D - |\rho_1| - |\rho_2|$ (D is the distance between circle centers and ρ's are the circle radii.) and $M_{2tracks}$ is mass reconstructed with two track momenta.

To estimate the efficiency and over-efficiency for conversion electron identification, the inclusive central electrons were selected requiring Et >12GeV, Had/EM < 0.05, $\chi^2_{strip}<10$, $\chi^2_{wire}<10$, LSHR < 0.2, $\Delta Z < 3.0$ cm, $\Delta r\phi < 1.5$ cm, E/P < 1.5 and Border Tower Et < 1.5 GeV. Out of these electrons, conversion electrons were identified by the above algorithm (a) or (b). The over-efficiency of conversion electron identification, i.e., the inefficiency of prompt electron detection is given by n_B/n , where n_B is the number of electron pairs with the same charge and n is the number of all electrons with tracks in VTPC. The efficiency of conversion electron identification, ε, is calculated using the ratio of the number of electrons satisfying both (a) and (b) to the number of electrons satisfying (a), $\varepsilon_1 = N_F/N$ as follows:

$$\varepsilon = (N + n_F - n_B)/ (N + (n_F - n_B)/\varepsilon_1),$$

where n_F is the number of electrons satisfying (b) with tracks in VTPC. The over-efficiency and the efficiency of conversion pair identification are 5.0 ± 0.3 % and 80 ± 3 %, respectively.

In this inclusive electron event sample, ~ 30% was found to be conversions.

5. The charge measurement of electrons and the background estimate with same-sign lepton pairs

The E/P distributions of electrons from W decay are shown in the central ($|\eta| < 1.1$) and plug ($1.3 < |\eta| < 1.7$) regions in Figs. 3a and 3b, respectively. The E/P distribution of central electrons are consistent with $W \rightarrow e\nu$ simulation including radiative correction as shown in Fig.3a. The E/P distribution of the plug electrons is broader than that of the central electrons by a factor of 3. It can be explained by the worse momentum resolution due to the shorter magnetic field length in $1.3 < |\eta| < 1.7$. The charge asymmetry in W decay electron was measured as shown in Fig.4. The charge of electrons from W decay can be determined in the pseudorapidity range $|\eta| < 1.7$.

The charge determination is important for background estimation in Drell-Yan physics and heavy flavour physics. In Drell-Yan physics, background sources are the $\pi^{\pm}$-π^0 overlaps, the π^0 /γ conversions, interactive $\pi^{\pm}$ in CEM or PEM and prompt electrons from b or c semileptonic decay. Out of these backgrounds, we can suppress and estimate the contamination of the $\pi^{\pm}$-π^0 overlaps using the quantities, E/P, ΔZ and $\Delta\phi$, and the contamination of the π^0 /γ conversions using the method described in previous section. About the interactive $\pi^{\pm}$ in CEM or PEM and prompt electrons from b or c semileptonic decay, we use ISOL(R<0.4) distribution to suppress and estimate their contaminations. We selected a dielectron event sample requiring two electrons with Pt > 6GeV/c, Had/EM < 0.055 + 0.045 x E (GeV)/100, $\chi^2_{strip} < 15$, LSHR < 0.2, ΔZ < 3.0 cm, $\Delta r\phi$ < 1.5 cm, E/P < 1.5 and an associated VTPC track, and $M_{ee} > 15$ GeV/c^2. The ISOL distributions are shown in Fig.5 for the opposite sign pairs by a solid line, and for the same sign pairs by a dashed line. We can see the ISOL distribution of backgrounds (mainly electrons from b or c semileptonic decay) from the same sign pairs, and can estimate the background contamination after the ISOL cut.

In the same way, we can study the background of top quark search in dilepton channel using the same sign pairs. We looked at scatter plots of electron Et versus muon Pt for the same sign e-μ pairs and the opposite sign e-μ pairs, and found that they showed very similar distributions to each other.

6. Summary

Electron identification at CDF is good enough for W/Z physics and heavy flavour physics. The tracking chamber with a solenoidal magnetic field at CDF is useful for

rejecting the backgrounds such as the $\pi^{\pm}$-π^0 overlaps, the π^0 /γ conversions and interactive $\pi^{\pm}$ in electromagnetic calorimeter, for prompt electrons: The E/P cut reject backgrounds for non-isolated electron sample (Et >10 GeV) by a factor of 20 at CDF. Requiring a tight track-cluster position match together with the E/P cut, we decrease the background contamination down to 3%. Tracking with magnetic field is powerful for rejection of conversion electrons. Charge of W electron can be measured in the range $|\eta| <$ 1.7 at CDF. Charge measurement of lepton is very effective for the background estimation in Drell-Yan physics and Heavy flavor physics.

From the above points, large coverage of solenoid in η is favourable for good identification of electron.

References

1) F. Abe et al., Nucl. Instrum. Methods Phys. Res., Sect. A **271**, 387 (1988).
2) F. Abe et al., Phys. Rev. Lett. **63**, 720 (1989)
3) F. Abe et al., Phys. Rev. Lett. **64**, 142 (1990)
4) F. Abe et al., Phys. Rev. Lett. **64**, 147 (1990)
5) F. Abe et al., Phys. Rev. Lett. **64**, 152 (1990)

Figure Caption

Fig.1. The E/P distribution for the central electromagnetic clusters with a track together with a histogram of multiplicity of associated tracks with the central electromagnetic clusters in the up-right side.

Fig.2. The distributions of the deviation of cluster centroid from associated tracks (a) in z direction without the E/P cut, (b) in ϕ direction without the E/P cut, (c) in z direction after the E/P cut and (d) in ϕ direction after the E/P cut, for the central electromagnetic clusters with a track.

Fig.3. The E/P distributions of electrons from W decay in (a) the central and (b) the plug regions together with the E/P for $W \rightarrow e\nu$ simulation including radiative correction.

Fig.4. A plot of the charge asymmetry in electrons from W decay versus electron pseudorapidity together with theoretical predictions with several structure functions.

Fig.5. The ISOL(R<0.4) distribution for electron pairs with the opposite charge (solid line) and the same charge (dashed line) in Drell-Yan event sample with Pt (e) > 6 GeV/c and $M_{ee} > 15 GeV/c^2$.

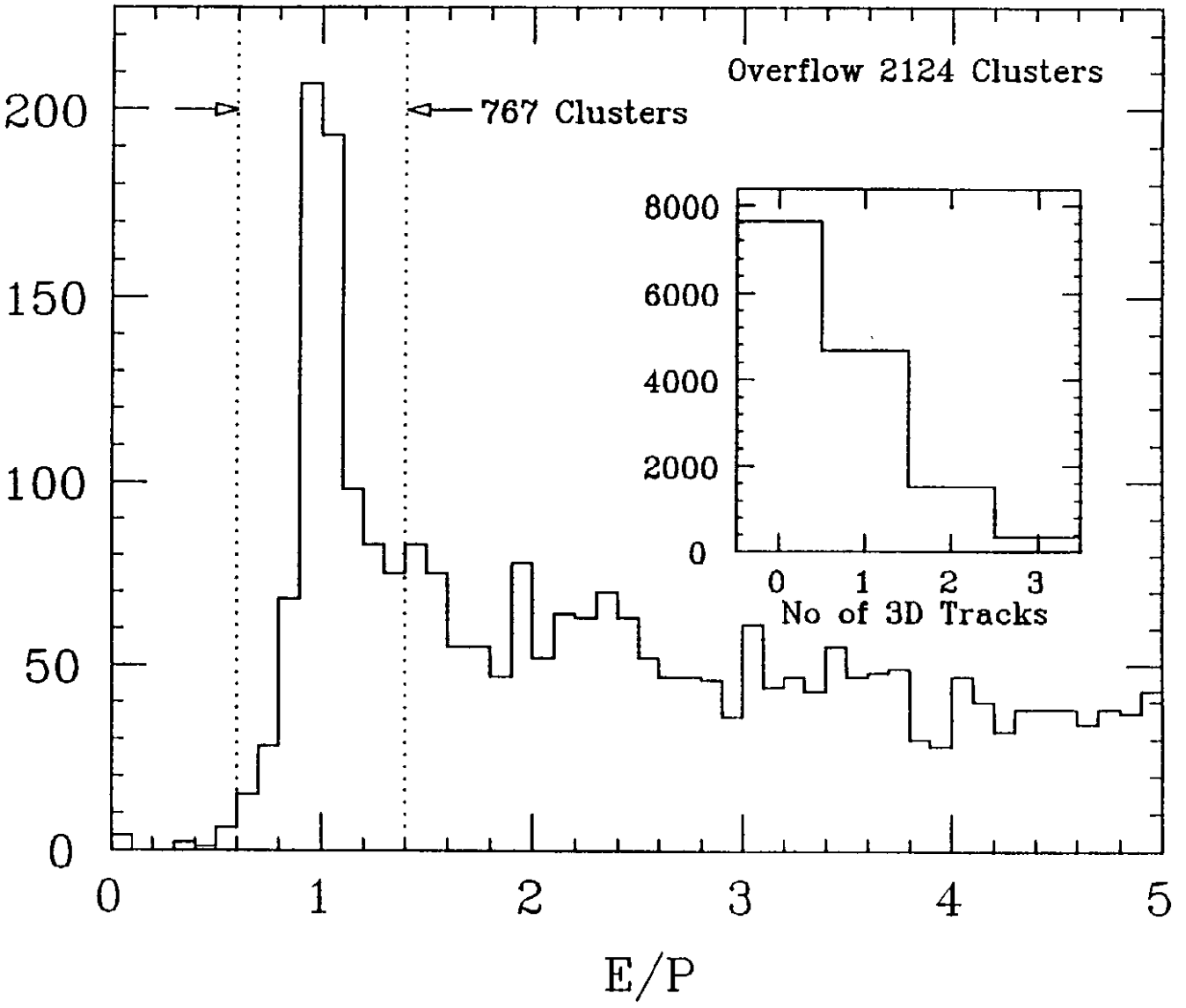
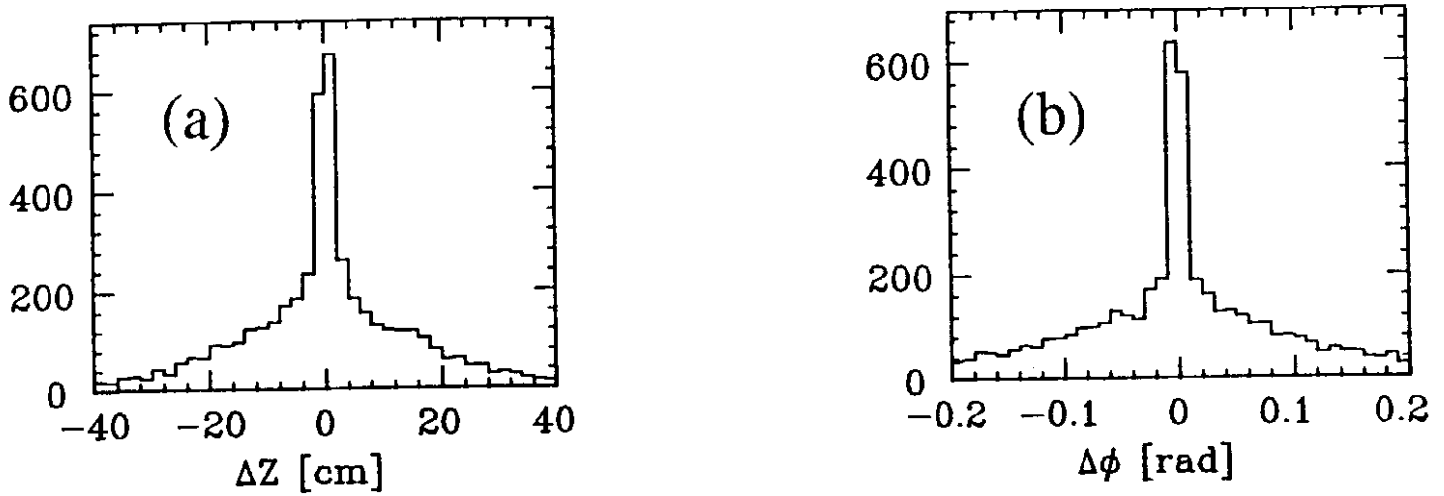

Overflow 2124 Clusters
767 Clusters
200
150
100
50
0
0
1
2
3
4
5
E/P
8000
6000
4000
2000
0
0
1
2
3
No of 3D Tracks

Fig.1

Track Matching to a CES Cluster without E/P Cut



Track Matching to a CES Cluster 0.6 < E/P < 1.4

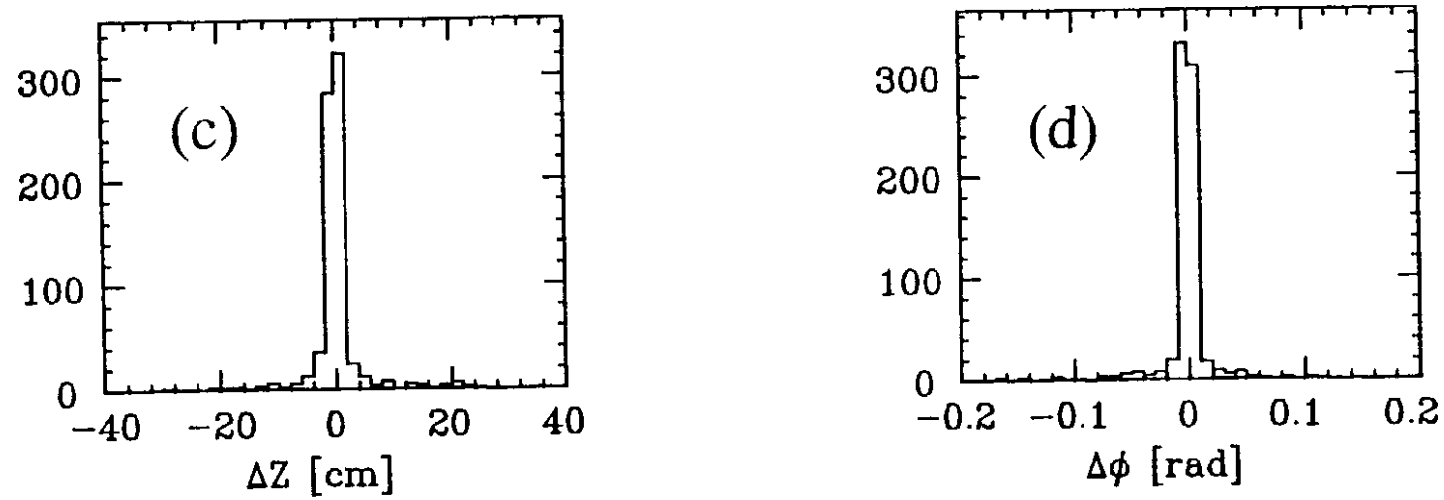
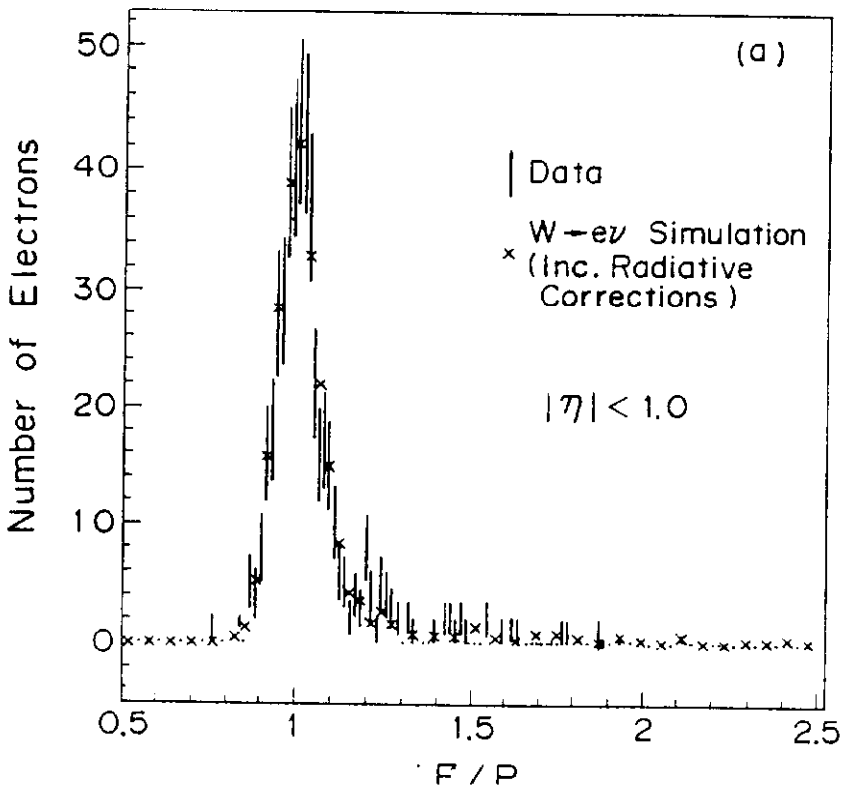


Fig.2


(a)
Data
W→eν Simulation
(Inc. Radiative
Corrections)
|η| < 1.0
Number of Electrons
E / P
0
10
20
30
40
50
0.5
1
1.5
2
2.5

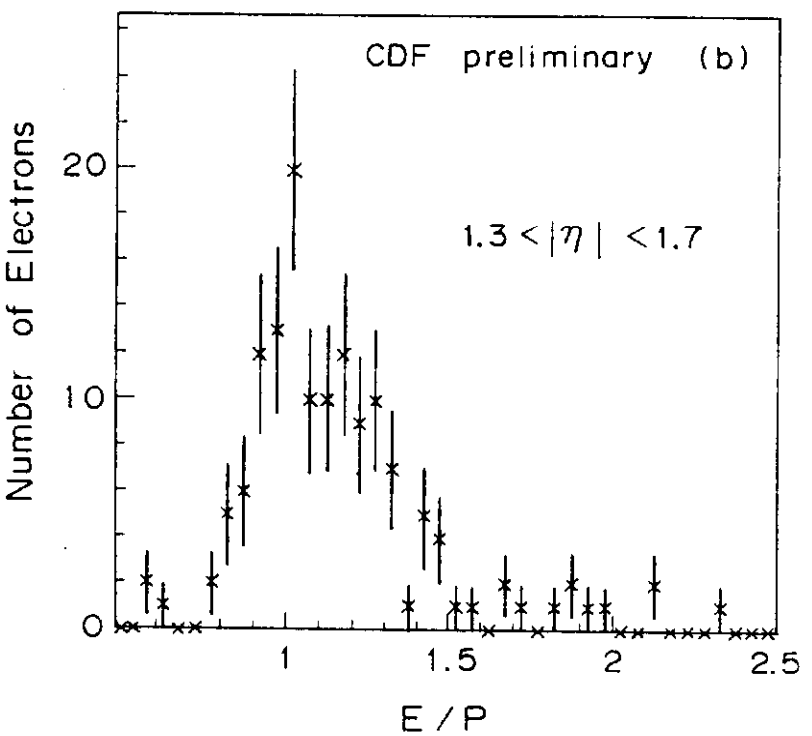

CDF preliminary (b)
1.3 < |η| < 1.7
Number of Electrons
E / P
0
10
20
1
1.5
2
2.5

Fig.3

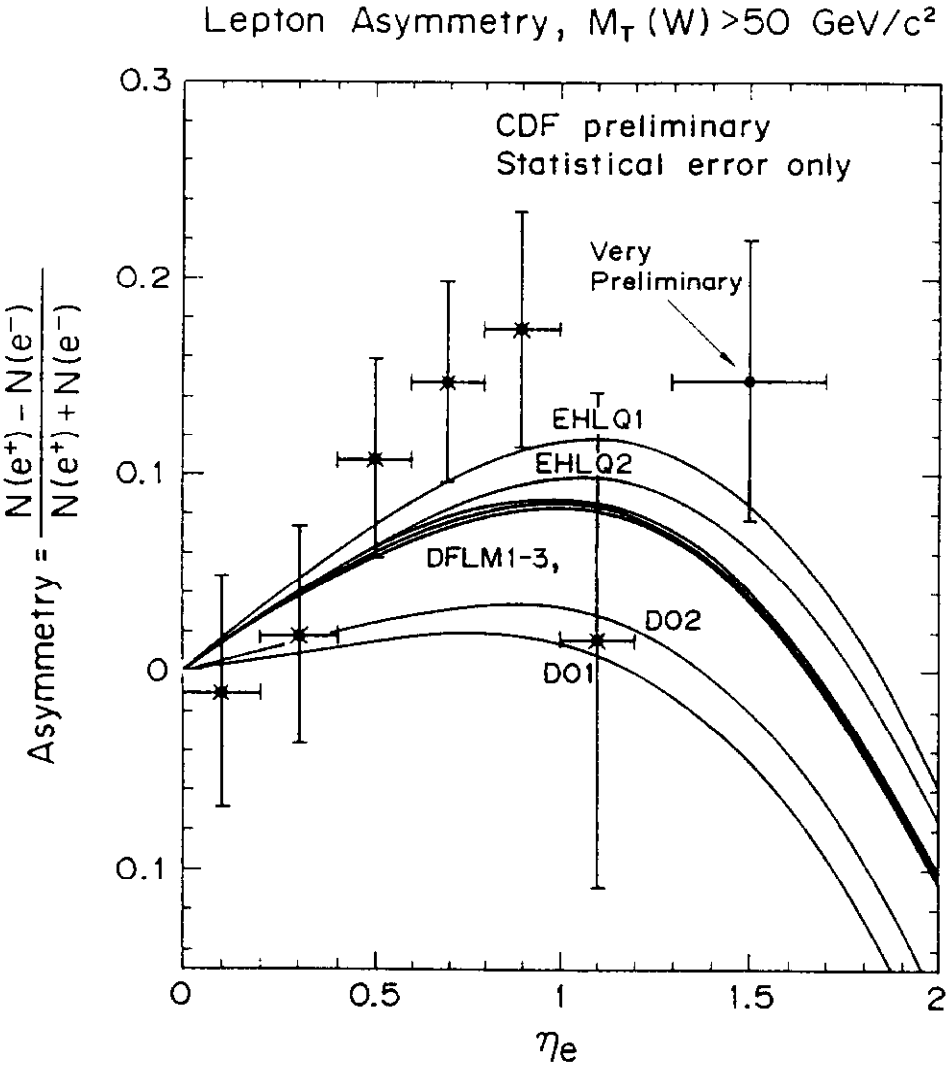

Lepton Asymmetry, M_T (W) >50 GeV/c^2
CDF preliminary
Statistical error only
Very
Preliminary
EHLQ1
EHLQ2
DFLM1-3,
D02
D01
Asymmetry = $\frac{N(e^+) - N(e^-)}{N(e^+) + N(e^-)}$
0.3
0.2
0.1
0
0.1
0
0.5
1
1.5
2
η_e

Fig.4

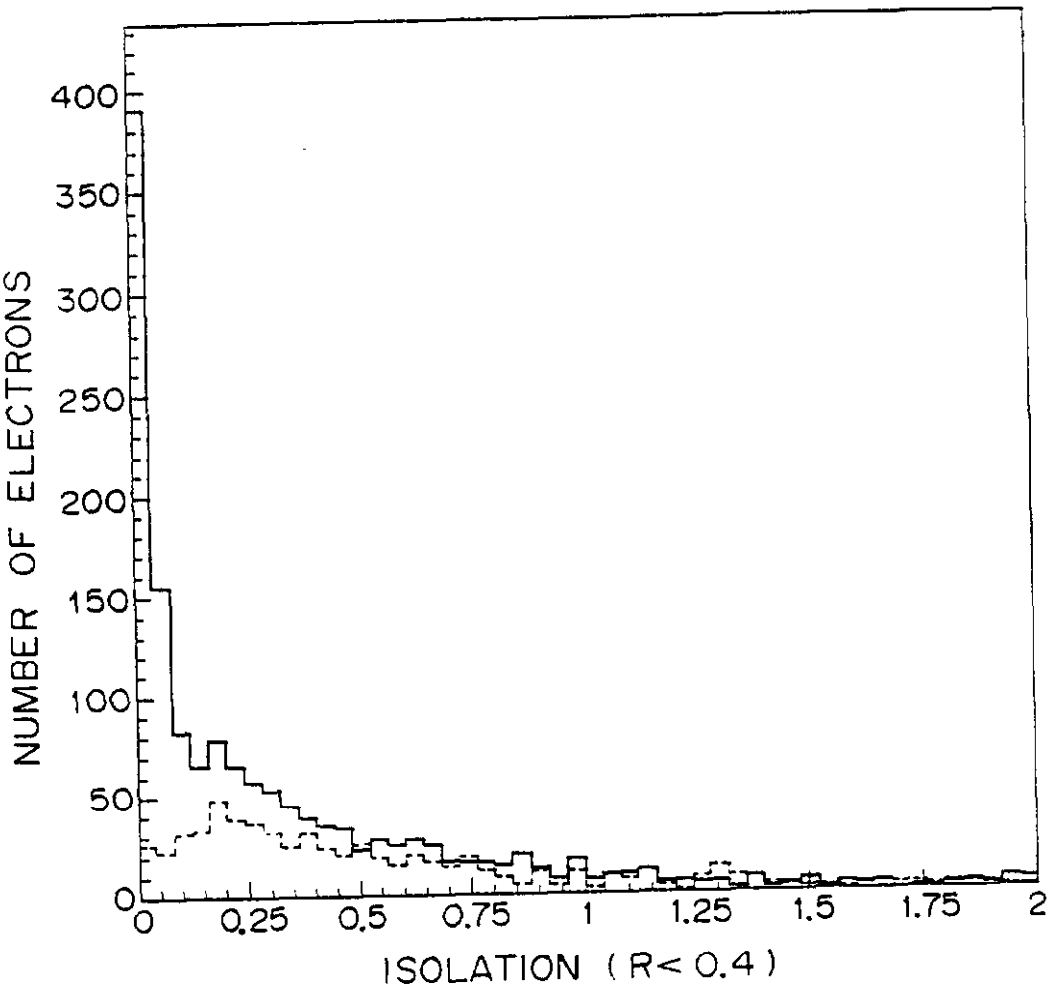

NUMBER OF ELECTRONS
400
350
300
250
200
150
100
50
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
ISOLATION (R< 0.4)

Fig.5